# Design and Measurement of Novel Dual Band Microstrip Patch Antenna for Radar Applications

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**Abstract.** This paper depicts a compact size, dual band antenna for X-band (radar) applications. The substrate material used between the patch and the ground is of FR4 (Flame retardant Version 4) Epoxy with a relative permittivity of 4.4. A novel shape is used here to make it more compact rather than that of the conventional shapes. The antenna resonates at two frequency bands, one at 9.19 GHz and 10.85 GHz. The range of X-band as defined by the IEEE standard 521 is about 8 GHz to 12 GHz for radar applications. Defected Ground Structure is used in the design to change the effectual capacitance and inductance of the antenna and to improve the overall performance. Finite Element Method (FEM) based software is used for modeling and analysis of the antenna. The overall dimension of the antenna is of 25.60 × 23.63 × 1.6 $mm^3$. A bandwidth of 600 MHz (6.53%) and 1650 MHz (15.20%) is obtained for the operating frequency of 9.19 GHz and 10.85 GHz respectively. Other parameters of the antenna like reflection coefficient, VSWR, gain, radiation pattern, and directivity are also conferred in this paper.

Keywords: Microstrip antenna, Defected Ground Structure, reflection coefficient, gain, directivity

## 1. Introduction

In the upcoming era, there is various usage of microstrip patch antenna in most of the wireless applications because of its compact size, low profile nature, etc. It consists of a dielectric substrate material inserted between the radiating metal patch and the conducting ground plane. The patch and the ground can be made of from any of the conducting material like copper, gold, etc., [1]. They are light weight planar structure, mechanically stiff, has the capability of low cost and easy manufacturing characteristics with printed circuit board technology [2]. Few applications of microstrip antenna are of satellite, radar, MIC and MMIC (Monolithic Microwave Integrated Circuits) [3].

The antenna size will be of larger value for low frequency application. In order to meet that requirement, methods such as engraving slots in the ground and patch [4], use of dielectric substrate with high relative permittivity have been done. But the latter lead to surface wave degradation. Also, for two or more frequencies of operation with limited size, the antenna is included with slits and slots on the patch along its radiating edges [5]. A U-shaped slot is most commonly used along the feed line to improve the characteristics with multiple frequencies of operation [6]. The U-shaped strip line used as feeding, with unequal arms has given a high gain value with dual band frequency of operation with optimal size [7]. Bandwidth is another important parameter to consider, with which stacked configurations [8] are used to improve the same, with a size reduction of 31% for a particular frequency of operation [9]. Mostly, the microstrip patch antenna provides narrow bandwidth and it was improved by providing stacked parasitic elements. It not only improves the bandwidth but also improves the gain performance of the antenna [10]. Also, fractal shaped antennas (patch shape will be of irregular structures formed by non-periodic configurations or periodic iterations) [11] like Sierpinski (repetition of triangular shaped structure) [12] and genetic-based configurations [13] have been used to provide broadband/multiband frequency of operation.

And the inclusion of Defected Ground Structure will surely enhance the performance of the antenna. Defected Ground Structure, shortly called as DGS is a defect or fractal shape which may be non-periodic or periodic in nature included in the ground plane with a purpose. When added, it changes the electrical and magnetic characteristics of the antenna and hence can help in tuning for lower frequency with miniaturization in size [14]. There are various shapes available for providing DGS in the ground plane such as concentric ring type [15], arrow headed DGS, dumb-bell shaped, open square loop, polygonal, etc, [16]. It can also be used to change the filter characteristics such as for Low Pass Filter [17] and for other filters [18]. Various shapes and configurations of patch antenna are available. Of which, here a combination of circle and rectangle is used for the consideration of novel shape, with line feeding technique used for excitation.

## 2. Design configuration

The proposed design model uses the FR4 dielectric substrate material with a relative permittivity ($\varepsilon_r$) of 4.4, loss tangent ($\delta$) value of 0.02 and thickness or height of 1.6 mm. The design structure consists of a novel shaped patch, as a combination of conventional shapes like circular and rectangular. The circular shape is placed at the center of the patch, with three rectangular shaped strips around it. Of those rectangular patch strips, one is used for feeding as a line feed. The ground plane comprises of a circular ring-shaped defect included in the partial ground. The antenna size is about 25.6 × 23.63 × 1.6 $mm^3$.

### 2.1. Design model and its parameter

The front and back view of the proposed antenna model structured using Ansoft High Frequency Structural

Simulator (HFSS), which is based on FEM (Finite Element Method) is given in Figure 1.

Each of the antenna dimensions of the proposed model is calculated using the conventional formulas, which are provided in literature surveys. The Length and breadth (Width) of the rectangular shaped structure in the design are considered from [2]. Similarly, the effective radius of the circle used at the center of the patch and the ground plane is formulated using the equations given in [2].

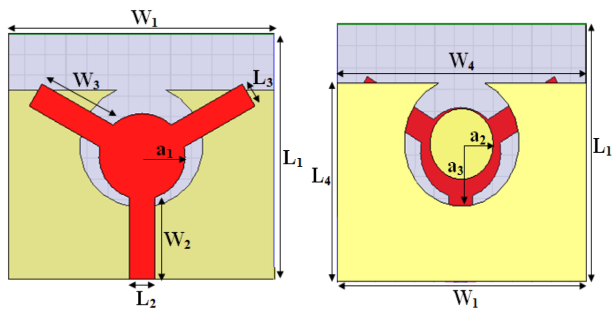
$$L_g = 6h + L \tag{1}$$

$$W_g = 6h + W \tag{2}$$

Eqs (1) – (2) are used for the calculation of the dimension of the rectangular shape, used at the ground plane.

The values of each of the variables used in the design model are given in the following Table 1.

The parameters $L_2$, $L_3$ and $W_2$ ($W_3$) are calculated for the resonant frequency of 11 GHz, based on the rectangular formulas. The radius of the circle $a_1$, $a_2$, $a_3$ in patch and ground respectively is calculated for a resonant frequency of 9.5 GHz. And all the values calculated are varied to some extent in order to obtain optimized results. The fabricated prototype of the proposed design is shown in Figure 2.




(a) Front Outlook (b) Back Outlook

Fig.1. Design Model of the depicted antenna

(a) Top view (b) Bottom view

Fig.2. Prototype of the fabricated antenna model

**Table 1**: Design parameters of the depicted antenna model

| Parameter | $L_1$ | $W_1$ | $L_2$ | $W_2$, $W_3$ | $L_3$ |
|---|---|---|---|---|---|
| Values in mm | 23.63 | 25.60 | 2.46 | 7.88 | 2.46 |
| Parameter | $L_4$ | $W_4$ | $a_1$ | $a_2$ | $a_3$ |
| Values in mm | 18.21 | 25.60 | 4.13 | 3.19 | 5.90 |

## 3. Results and discussion

In this section, the simulated and measured parameters of the proposed model are discussed. The characteristics of the proposed model such as reflection coefficient, gain, VSWR, bandwidth, radiation patterns, efficiency and current distribution are simulated using Ansoft High Frequency Structural Simulator (HFSS) are conferred as follows. The measurement setup for the calculation of reflection coefficient and VSWR are shown in Fgures 3 and 4, respectively.

### *3.1. Reflection coefficient*

The simulated and measured result of the reflection coefficient are obtained using Ansoft HFSS and ZVL Network Analyzer respectively, are represented in Figure 5. It is evident that the antenna resonates at two distinct frequency bands centered at 9.19 GHz and 10.85 GHz respectively. A bandwidth of 600 MHz and 1650 MHz is obtained for the first and second resonant frequency, respectively. The simulated and measured values of reflection coefficient are in good agreement.

### *3.2. VSWR*

VSWR (Voltage Standing Wave Ratio) of the proposed antenna model is given in Figure 6. The VSWR value lies between 1 and 2 for the given resonant frequencies with a value of 1.14 and 1.03 correspondingly.

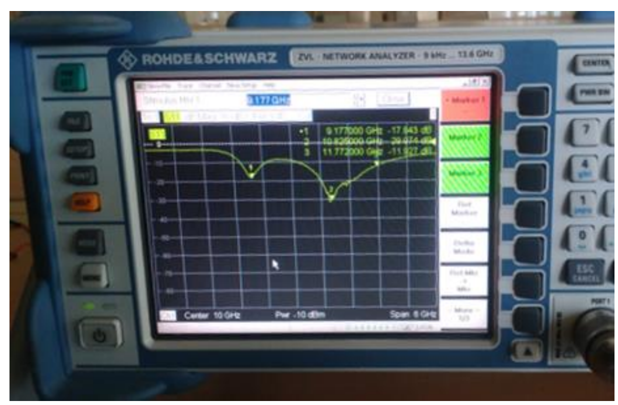



Fig.3. Measured reflection coefficient of the fabricated antenna

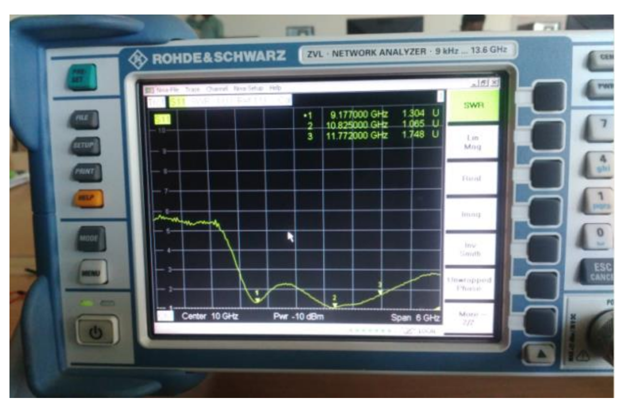



Fig.4. Measured VSWR of the fabricated antenna

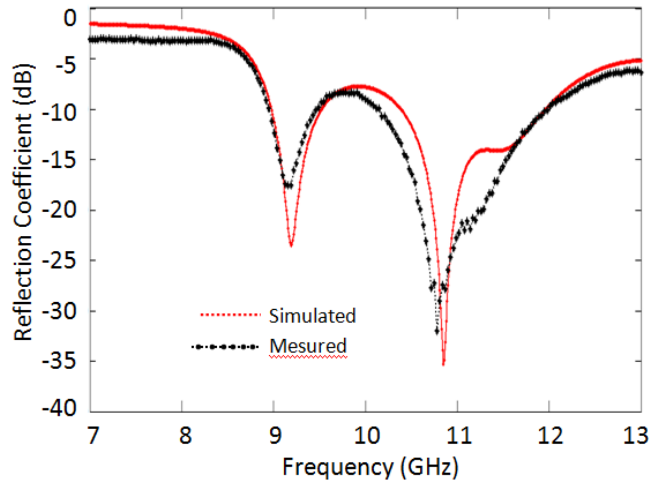



Fig.5. Simulated and measured reflection coefficient

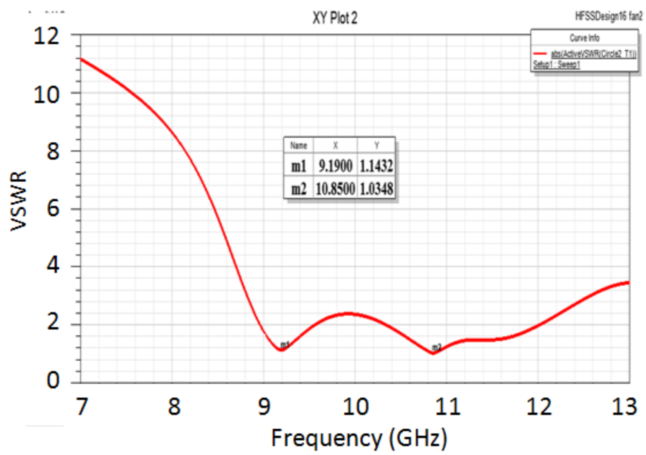
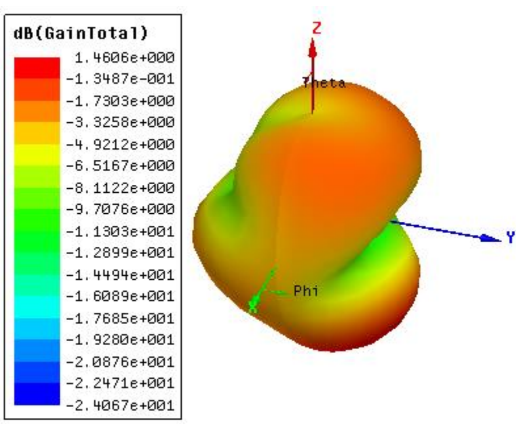



Fig.6. VSWR vs Frequency (GHz) graph of the antenna

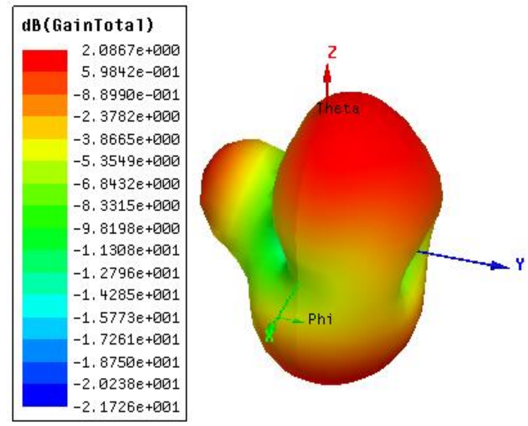
### *3.3. Other parameters*

The other parameters such as gain, surface current distribution, radiation patterns and efficiency of the proposed model are simulated using the Ansoft HFSS is described in this section.

A gain value of 1.46 dBi and 2.08 dBi was obtained for the first and second resonant frequency and is shown in Figure 7.




(a) At 9.19 GHz

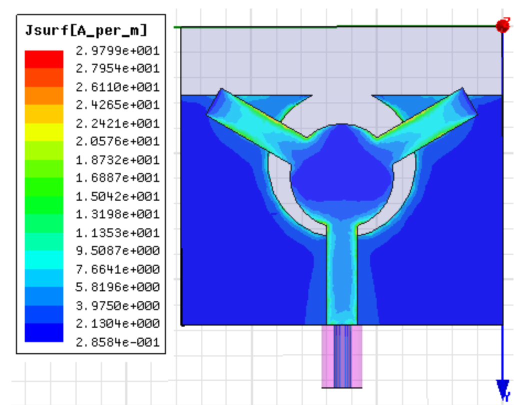



(b) At 10.85 GHz

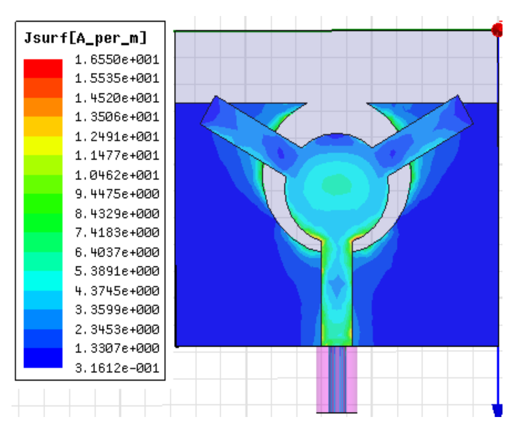
Fig.7. 3D gain plot of the proposed model (simulated)

The surface current distribution predicts the resonance characteristics of the antenna and is shown in Figure 8. For the first resonant frequency, the maximum radiation is produced along the edges of the rectangular strips provided. Whereas for the second resonant frequency, the radiation or excitation is due to the feed line and the DGS provided.

The efficiency of the antenna is of 75.26 % and 78.98 % for the first and second resonant frequency. The simulated comparison of gain and efficiency vs frequency is plotted in the Figure 9.




(a)




(b)

Fig.8. Current Distribution at (a) 9.19 GHz, (b) 10.85 GHz

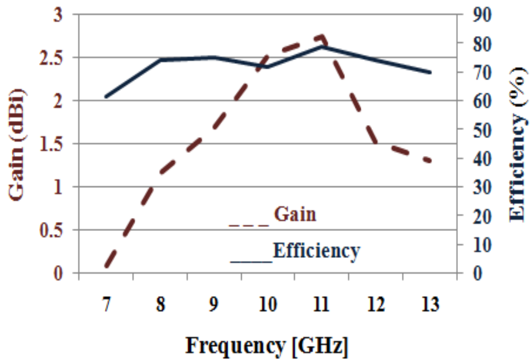



Fig.9. Gain and efficiency plot (Simulated) of the depicted antenna

The simulated radiation patterns of the proposed antenna for the resonant frequency of 9.19 GHz and 10.85 GHz correspondingly is shown in Figure 10. With the dotted lines representing the E-field pattern (XZ plane) with the consideration of theta = all values and phi (ϕ) = 0º. And with phi (ϕ) = 90º and all values of theta, the H-field pattern (YZ plane) is calculated and is given by a solid line in Figure 10. The directivity obtained is about 2.79 dB and 3.46 dB for the resonant frequency of 9.19 GHz and 10.85 GHz respectively.

## 4. Conclusion

As mentioned in the above sections, the proposed model is well suited to perform better as a radar antenna with the resonant frequencies lying between the X-band ranges. The bandwidth obtained is of high value, which is greater than 500 MHz (Ultra Wide Band) for both of the resonant frequencies with its compact size. The simulated and measured value of return loss and VSWR coincides in a greater manner. And thus, this proposed antenna with considerable value of gain, VSWR, return loss, directivity, efficiency and bandwidth is well suited for X-band radar applications, particularly police radar application.

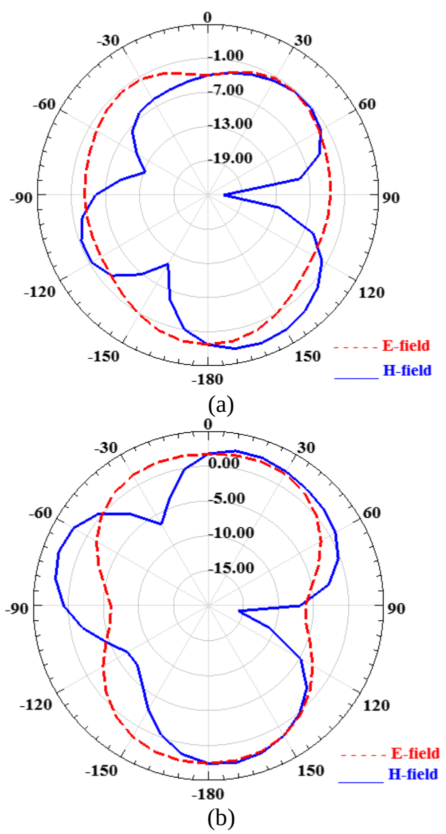



Fig.10. E-field and H-field plot (a) 9.19 GHz (b) 10.85 GHz

## Acknowledgement

The authors would like to thank Dr. S. S. Karthikeyan, Indian Institute of Information Technology Design and Manufacturing (IITDM), Chennai for providing their facilities and infrastructure for testing and measurement of the antenna parameters.

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